Sandia National Laboratories

Assessment of Sandia's 2021 Pilot Program for Research Traineeships to Broaden and Diversify Fusion Energy Science: Development and Rapid Screening of Refractory Multi-Principal Elemental Composites for Plasma Facing Components

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ACRONYMS AND DEFINITIONS

Abbreviation	Definition
AML	Advanced Materials Laboratory
FAMU	Florida A&M University
FES	Fusion Energy Sciences
HBCU	Historically Black Colleges and Universities
MSI	Minority Serving Institutions
NCAT	North Carolina A&T
NP	Nuclear Physics
SNL	Sandia National Laboratories
START HBCU	Securing Top Academic Research and Talent

1. BACKGROUND

The Fusion Energy Sciences office supported "A Pilot Program for Research Traineeships to Broaden and Diversify Fusion Energy Sciences" at Sandia National Laboratories during the summer of 2021. This pilot project was motivated in part by the Fusion Energy Sciences Advisory Committee report observation that "The multidisciplinary workforce needed for fusion energy and plasma science requires that the community commit to the creation and maintenance of a healthy climate of diversity, equity, and inclusion, which will benefit the community as a whole and the mission of FES". The pilot project was designed to work with North Carolina A&T (NCAT) University and leverage SNL efforts in FES to engage underrepresented students in developing and accessing advanced material solutions for plasma facing components in fusion systems. The intent was to create an environment conducive to the development of a sense of belonging amongst participants, foster a strong sense of physics identity among the participants, and provide financial support to enable students to advance academically while earning money. The purpose of this assessment is to review what worked well and lessons that can be learned. We reviewed implementation and execution of the pilot, describe successes and areas for improvement and propose a no-cost extension of the pilot project to apply these lessons and continue engagement activities in the summer of 2022.

2. IMPLEMENTATION AND EXECUTION OF THE PILOT

The proposal for an initiative to improve diversity and inclusion for the fusion community grew out of a Nuclear Physics FOA. Two Sandia staff members, LaRico Treadwell and Khalid Hattar, with deep involvement in material development and Sandia's Securing Top Academic Research and Talent (START HBCU) worked with colleagues in the NCAT nuclear physics department to propose a collaborative program in radiation resistant silicon carbides. Sandia was not eligible for an NP sponsored program because we do not have active programs with the office. With the encouragement of the FES office, the Sandia team pivoted the proposal to radiation resistance refractory metals which are of considerable interest to future fusion plants. We received a go-ahead on March 21, 2021 and funding on July 2, 2021. We recruited student interns through Sandia's START HBCU program. Because the students were able to start up to 7-8 weeks before the funding arrived, we supported them for part of the summer out of synergistic programs.

3. ASSIGNMENTS AND ENRICHMENT ACTIVITIES FOR THE STUDENTS

Students were recruited to work within the Materials, Physical and Chemical Sciences Center at Sandia. Two students worked on-site at the Advanced Materials Laboratory and one student worked remotely with the Computational Materials and Data Science Department. The on-site students were trained in operating safely in a modern materials discovery, development, and characterization laboratory. Techniques employed included high temperature chemical synthesis, operation in an inert atmosphere glovebox, materials processing with a hot isostatic press, materials characterization using multiple analytical techniques including powder X-ray diffraction, thermogravimetric analysis, multiple spectroscopy techniques and scanning electron microscopy. While at AML, the students collaborated with the digital manufacturing lab and gained appreciation for the multiple modalities of additive and advanced manufacturing that could be employed in generation of materials for applications in fusion energy. Additionally, the students were given tours of Sandia's National Security suite covering a plethora of technologies that Sandia has contributed to the benefit of a

variety of missions. Students also toured the National Museum of Nuclear Science and History, the Ion Beam Lab and the National Solar Thermal Test Facility. These tours served to give students a broad view of Sandia activities as well as an appreciation for the breadth of energy research carried out.

4. SUMMARY OF POST-PROGRAM INTERVIEWS WITH THE STUDENTS

Bria Cook: Bria Cook is currently a Chemistry Major working on her BS and will graduate in spring 2022. Prior to her internship she had planned to further her education through attendance at a Pharmacy graduate program. From the influence of her mentors and others she worked with at the AML during her internship, she has decided to apply for grad school this fall, to pursue a PhD in Chemistry. She is applying to NC Chapel Hill, University of Michigan, NC State, LSU, and the University of Illinois. Bria says, "This internship has opened my eyes to so many things in science that I didn't know, and it made me realize that I want to go to graduate school to get my PhD, which was never in my plan, for after my undergraduate degree". This decision is partly due to her positive experience here at Sandia. Bria continued, "I really liked working with my mentors and all the people at the AML, they were all very open and nice to me all summer and made me feel very welcome. I liked the exposure to composite processing". On the experience she got at the AML this summer, Bria stated, "They educated me on polymer and composite chemistry, and the different opportunities available if I were to pursue a PhD in Chemistry". Bria also found the tours very useful, "I really liked the IBL tour, as it gave me an idea of what people in other laboratories around Sandia do at their job". Bria hopes to return to Sandia for another internship. At an NCAT career fair in mid-September, she signed up to see the recruiter from Sandia to explore other laboratory internships. This was her first time in New Mexico, and she really liked Albuquerque, and the weather.

Eryal Rhinehart, a Sophomore in Mechanical Engineering, heard about this internship through her father, who also works at Sandia. This was her first internship experience. She is from Albuquerque. Eryal found her summer Sandia internship experience at the AML to be very valuable, and commented, "I like the way everyone at the AML was close-knit, and worked together, and all staff were easily accessible if I had questions, it was good to meet so many people that can help me". Eryal worked on composites, Carbon fiber silicon, and filled in gaps with nanoparticles, and one of her mentors examined the samples that she made. Eryal loved her work with her mentors, "the summer internship was really good for me, when I came here, I was thinking that I wanted to do CAD design work, but now that I've had the internship, I want to do work that involves more hands-on like being an experimentalist". Like Bria, this internship experience had a changing influence on her career directions as well, "I want to change my major from Aerospace Engineering to Material Science, and hope to work in the Aerospace industry using my Material Science degree." Eryal found this internship experience so valuable that she wants to return next summer for her second summer, "next summer I plan to try to get another internship at Sandia, but I'd like to try CAD computer design opportunities to make sure I want to change the direction of my career choice". When asked for a summarizing statement, Bria thought for a moment and said, "I thought the AML was a really great place to work for this summer, I'm really glad I got the opportunity".

Lester Coney, a Sophomore majoring in Computer Science, is already using information he learned during his summer Sandia internship, at school for this fall, *e.g.,* Linux clusters, and python scripting, and running HP environment computing. He is impressed by how much of his summer internship experience has already carried over into his schoolwork. Lester heard about this Sandia internship opportunity near the end of the spring semester, from an email sent out by his academic advisor there at NCAT. He was able to apply and was surprised how quickly he heard back from Sandia that he'd been accepted and would have a summer internship in a working from his home near Chicago. He enjoyed working with Mary Alice Cusentino, his Sandia mentor in the Computation Material Science department. Mary Alice worked with him to get him a Sandia owned computer and set up on the Sandia network from his remote location. Lester stayed at his home throughout his entire internship. The computational nature of his work allowed for this approach to be successful. Lester found his remote work experience to be satisfying. Lester said, "I really like getting to understand the inner workings of Sandia, and what they do. Before I started, I knew Sandia was a National Laboratory, but I had no idea about everything they did. Through all the available seminars and the Daily News Bulletin I received in emails, and the Sandia internal website, I was able to learn a lot about the lab".

Other positive attributes Lester took from his summer internship, were that he liked freedom to be able to learn new stuff with Sandia providing the resources to help him learn, *e.g.*, a crash course on Machine Learning and a course to quickly learn Python; he very much appreciated that somebody at Sandia sent him a Professional Development Webinar link that was 6 weeks long (once/week). Although he worked completely remote, he was able to participate in a virtual tour of the Z machine, which he "really liked too!". In general, Lester liked the project he was working on and learning a lot about Fusion Energy Science Materials.

5. REFLECTIONS OF THE MENTORS

Dr. Mary Alice Cusentino: While having our computational summer intern, Lester Coney, onsite would have been ideal, working remotely with Lester worked well in terms of the technical and mentor experience. Because his work focused on atomistic modeling, the technical aspect of his summer research was not detrimentally affected. I was still able to meet with him on a regular basis, as would have happened if Lester were onsite, and was able to guide Lester through the process of learning to run the simulations and use Sandia's high performance computing resources adequately over virtual meetings. This was helped by Lester's motivation to learn about fusion energy and atomistic modeling which made it easier for me to work with a remote intern. Had he not been as interested in learning the technical work, it might have been more difficult to work with a student remotely. At this point, due to the ongoing COVID-19 pandemic, working with Lester virtually was the ideal case at least in terms of our interactions. This success in having a virtual intern, at least form the perspective of the technical work, could potentially work for future interns although other aspects of the summer intern experience would need to be improved. It would still be ideal to have the summer interns come to Sandia in person but given the circumstances, the mentor experience was adequate.

Dr. LaRico Treadwell: Eryal Reinhart and Bria Cook were able to come onsite to participate in the design and development of refractory multicomponent alloys and metal matrix composites through

additive manufacturing and advance processing routes. Challenges associated with the delayed recruiting efforts as well as the pandemic limited the time the students were able to work onsite. Even with this limitation, I was able to meet the students daily and perform initial experiment in the design and development of the alloys as well as start the initiation of evaluation the microstructural characterization and rapid screening of the material. Upon the completion of the internship experience their interest in FES and materials development grew. In the future it would be beneficial to optimize the time onsite for the interns to facilitate more time in the lab. The time duration was too short for them to really complete and understand the depth of the project

6. TECHNICAL ACCOMPLISHMENTS

Eryal Reinhart and Bria Cook

- Investigated a novel route to fabricate alloys with inclusions using a hot isostatic press
- Utilize spectroscopy tools to investigate the surface and microstructures of 3D printed metal alloys to directly compare to alloys produced by hot isostatic press.
- Gained exposure to gamma and ion irradiation facilities, as well as advanced electron microscopy approaches.
- Worked with Sandia chemist LaRico Treadwell to prepare the Advanced Materials Lab for a science day for 200 Albuquerque 4th graders, who visited from screens. The lab's primary focus in on the synthesis, characterization, processing, and manufacturing of materials.

Lester Coney

- Ran molecular dynamics simulations of helium and hydrogen implantation and bubble growth in tungsten carbide
- Utilized high performance computing resources at Sandia to perform atomistic simulations and learned a variety of new computer science skills include bash terminal commands and python

7. WHAT PIPELINE DEVELOPMENT CONCEPTS WORKED?

The project identified promising talented students from NCAT, helped them develop new skills, exposed them to the excitement of fusion research and other STEM careers. The activities and experiences provided a good window into the life of a research scientist. Their accomplishments and experiences will bolster future success. Two of the students' experiences as interns in the FES Pilot program solidified their graduate pursuits. The interviews with the students indicate that they enjoyed the program, learned a lot, and developed significantly new perspectives.

The Sandia researchers learned from the students as well. They were inspired by the energy and enthusiasm that the students brought to the internships. Their experiences will serve Sandia and the fusion program well on our journey to an ever more diverse and inclusive environment.

8. AREAS FOR IMPROVEMENT

Costing: The project only spent $19K out of the $100K allocated to the pilot. The funding request was based on supporting four students for 10 weeks each. Of the four students planned, we were

only able to recruit three. Two of the three students participated for only 4 and 5 weeks, respectively. Because the FES funds arrived later than the students, they were supported by synergistic programs for up to 7 weeks. We budgeted $12K for 8 trips including travel to and from Sandia and for field trips. These funds were not executed because Sandia's corporate Human Resources department supported travel and because COVID considerations reduced the feasibility of additional travel. Most of these issues have their root in the late start recruiting.

Recruiting: We began recruiting in early April after receiving approval from FES. Adequate recruitment efforts were difficult because most candidates had already secured other internships. A few potential candidates were uncomfortable relocating to Albuquerque because of concerns over COVID-19. Recruiting would be more successful if begun earlier.

Scheduling: The student experience was quite short in 2021. The short duration reduced their ability to make individual contributions and support the program. The student impact and costing could be improved by asking interns to commit to 8-10 weeks. Earlier recruiting would help with this request.

Remote work experience: While the technical experience for our remote summer intern, Lester Coney, was not substantially hindered by being offsite, he still missed out on critical components of the Sandia intern experience by being remote. Most importantly, he was not able to participate in networking with other staff member or summer interns which is a key part of being an intern. The opportunities for him to engage with typical summer internship activities, like tours, seminars, and the technical showcase, were limited. His mentor felt that he missed out on important summer intern activities and Lester himself discussed how he would have preferred to be at Sandia or at least be able to visit Sandia during his internship

Strengthen the relationship to HBCUs and Minority Serving Institutions (MSI)schools to build sustained partnerships in FES research: The Nuclear Physics program at NCAT did not shift emphasis from NP to FES relevant materials during the spring of 2021. A diverse and broad pipeline is critical to grow and innovate within the FES community. Our vision is to partner with one or more MSIs to expand the diversity and creativity of FES research. Collaboration with research teams at these schools will strengthen the FES community and improve the effectiveness of the pipeline. The collaborating Professors at these institutions could contribute to cutting edge research and identify promising upper-division or graduate students to partake in FES work. Collaboration with Sandia will strengthen both programs through internships that promote the pursuit of graduate degrees potentially leading to FES careers.

9. PROPOSAL FOR A NO-COST EXTENSION

We request a no-cost extension to the original project. The $81K of remaining funds will support four upper-division students for 10-week internships. Sandia will leverage existing programs to make up any short-falls and will cover relocation travel with corporate resources.

Based on lessons learned, we will begin recruiting immediately and target upper division students from the institutions below who express interest in fusion energy.

We encourage the FES office to seed research efforts at interested HBCU schools and have already identified at least one HBCU research group with an interest in Fusion Energy Sciences: FAMU Rebekah Sweat would like to develop research activities in atomistic modeling in partnership with our FusMatMl program. We are actively seeking partnerships with other institutions

10. CONCLUSION

The pilot project positively influenced the careers and improved future opportunities for three talented students. As a society, we benefit if historically black college and university students are energized and better qualified to pursue any science, technology, engineering, or mathematics career. By recruiting earlier, we can make the experience even more productive and rewarding for participants. We request a no-cost extension of the pilot project funding to apply lessons learned in the summer of 2022. Strengthening HBCU research programs in fusion is clearly important to building pipelines into FES interests. We would like to work with the FES office on national initiatives to accomplish this objective.